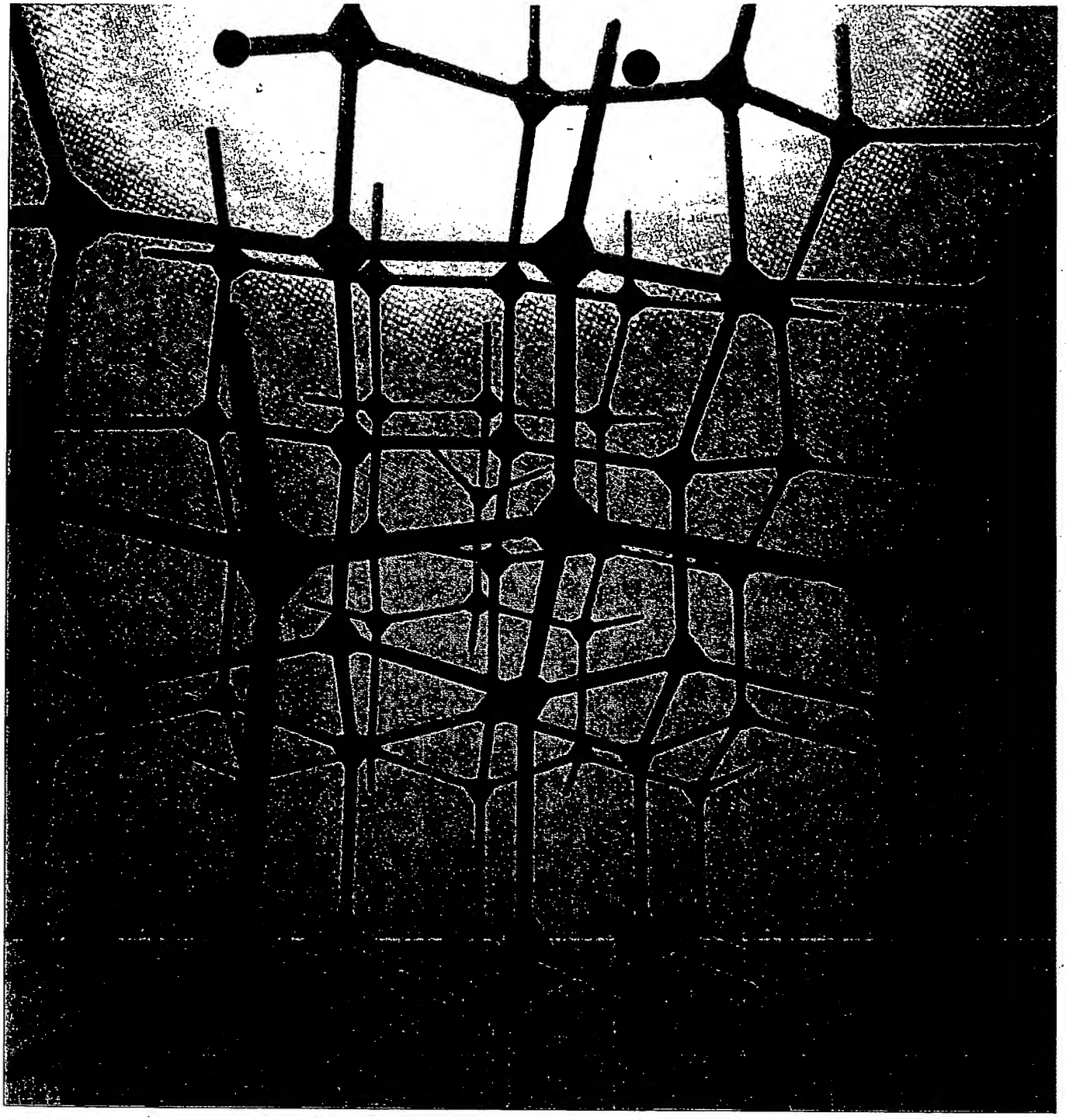

PRINCIPLES OF MODERN CHEMISTRY

DAVID W. OXTOBY
The University of Chicago

NORMAN H. NACHTRIEB†
The University of Chicago
University of Illinois at Chicago

THIRD EDITION

Saunders Golden Sunburst Series
SAUNDERS COLLEGE PUBLISHING
Harcourt Brace College Publishers

Fort Worth Philadelphia San Diego New York Orlando Austin
San Antonio Toronto Montreal London Sydney Tokyo

Text Typeface: Times Roman
Compositor: York Graphic Services
Publisher: John Vondeling
Developmental Editor: Elizabeth Rosato
Picture Developmental Editor: George Semple
Managing Editor: Carol Field
Project Editors: Margaret Mary Anderson and Bonnie Boehme
Copy Editor: Mary Patton
Manager of Art and Design: Carol Bleistine
Art Directors: Anne Muldrow and Caroline McGowan
Art Assistants: Sue Kinney and Kathleen Flanagan
Text Designer: Kathryn Needle
Cover Designer: Kathryn Needle
Text Artwork: Rolin Graphics
Layout Artist: Dorothy Chattin
Director of EDP: Tim Frelick
Production Manager: Joanne M. Cassetti
Marketing Manager: Marjorie Waldron

Cover Credit: Leonardo Ferrante/Tony Stone Images

Credit for Frontmatter and Backmatter Photos and for All Non-credited Photos Appearing in the Text: C. D. Winters

Title page: The structure of diamond consists of a network of interlocking tetrahedral carbon atoms.

Printed in the United States of America

PRINCIPLES OF MODERN CHEMISTRY
THIRD EDITION

ISBN 0-03-005904-6

Library of Congress Catalog Card Number: 95-067824

78901234 032 10 98765

Table 23-5 Plastics

Name	Structural Units	Properties	Sample Uses
Polyethylene	$-(CH_2-CH_2)_n-$	High density: hard, strong, stiff	Molded containers, lids, toys, pipe
		Low density: soft, flexible, clear	Packaging, trash bags, squeeze bottles
Polypropylene	$-(CH_2-CH(CH_3))_n-$	Stiffer, harder than high-density polyethylene; higher melting point	Containers, lids, carpeting, luggage, rope
Polyvinyl chloride	$-(CH_2-CH(Cl))_n-$	Nonflammable, resistant to chemicals	Water pipes, roofing, credit cards, records
Polystyrene	$-(CH_2-CH(C_6H_5))_n-$	Brittle, flammable, not resistant to chemicals, easy to process and dye	Furniture, toys, refrigerator linings, insulation
Phenolics	Phenol-formaldehyde copolymer	Resistant to heat, water, chemicals	Plywood adhesive, Fiberglas binder, circuit boards

Adapted from P. J. Chenier, *Survey of Industrial Chemistry* (John Wiley & Sons, New York, 1986), pp. 252–264.

whose cross-linking was discussed earlier in this section. Table 23-5 lists some of the most important plastics and their properties.

Ethylene ($CH_2=CH_2$) is the simplest monomer that will polymerize. Through free-radical-initiated addition polymerization at high pressures (1000–3000 atm) and temperatures (300–500°C), it forms polyethylene:

$$n\,CH_2=CH_2 \longrightarrow -(CH_2-CH_2)_n-$$

The polyethylene formed in this way is not the perfect linear chain implied by this simple equation. Free radicals frequently abstract hydrogen from the middles of chains in this synthesis, and so the polyethylene is heavily branched with hydrocarbon side chains of varying length. It is **low-density polyethylene** (LDPE) because the difficulty of packing the irregular side chains gives it a lower density ($<0.94\ g\ cm^{-3}$) than that of perfectly linear polyethylene. This irregularity also makes it relatively soft, and so its primary uses are in coatings, plastic packaging, trash bags, and squeeze bottles in which softness is an advantage, not a drawback.

A major breakthrough occurred in 1954, when the German chemist Karl Ziegler showed that ethylene could also be polymerized with a catalyst consisting of $TiCl_4$ and an organoaluminum compound (for example, $Al(C_2H_5)_3$). The addition of ethylene takes place at each stage within the coordination sphere of the titanium atom, so that monomers can add only at the end of the growing chain. The result is linear polyethylene, also called **high-density polyethylene** (HDPE) because of its density